

add B1

CLAIMS

1. A magnetic read head that has an air bearing surface (ABS), a read region that has first and second sides that extend substantially perpendicular to the ABS, first and second end regions that are adjacent said first and second sides respectively and the read region and the first and second end regions being adjacent said ABS, the magnetic read head comprising:

a read sensor located in the read region and having first and second side edges that define said first and second sides of the read region;

said read sensor including:

a ferromagnetic free layer and a ferromagnetic pinned layer; and

an electrically conductive non-magnetic spacer layer sandwiched between the free and pinned layers;

first and second lead layers located in the first and second end regions, each lead layer having a first side edge wherein the first side edge of the first lead layer is adjacent the first side edge of the read sensor and the first side edge of the second lead layer is adjacent the second side edge of the read sensor;

first and second read gap layers wherein each read gap layer is located in the read and first and second end regions;

first and second shield layers;

the read sensor and the first and second read gap layers being sandwiched between the first and second shield layers;

the first read gap layer comprising a bi-layer of an insulation film and an antiferromagnetic oxide film sandwiched between the first shield layer and the first lead layer in the first end region, sandwiched between the first shield layer and the read sensor

in the read region and sandwiched between the first shield layer and the second lead layer in the second end region;

the free layer being located between the antiferromagnetic oxide film and the pinned layer; and

the first and second lead layers exchange coupling to the antiferromagnetic oxide film and magnetostatically coupling to the read sensor.

2. A magnetic read head as claimed in claim 1 wherein the read sensor further includes:

an antiferromagnetic metallic layer exchange coupling to the pinned layer; and
a non-magnetic layer sandwiched between the free layer and the antiferromagnetic oxide film in the read region.

3. A magnetic read head as claimed in claim 2 including:
each of the first and second lead layers having a ferromagnetic film; and
the ferromagnetic film of each of the first and second lead layers exchange coupling to the antiferromagnetic oxide film in the first and second end regions respectively and magnetostatically coupling to the read sensor.

4. A magnetic read head as claimed in claim 3 wherein each lead layer includes:

non-magnetic adhesion and cap films;
an electrically conductive non-magnetic film sandwiched between the non-magnetic adhesion and cap films; and

in each of the first and second lead layers, the ferromagnetic film being sandwiched between the antiferromagnetic oxide film and the adhesion film in the first and second end regions.

1 5. A magnetic read head as claimed in claim 4 wherein the
2 antiferromagnetic metallic layer is selected from the group Ir-Mn, Ni-Mn, Rh-Mn, Pt-
3 Mn, Pd-Pt-Mn and Cr-Pt-Mn.

1 6. A magnetic read head as claimed in claim 4 wherein the
2 antiferromagnetic oxide film is selected from the group NiO and α -Fe₂O₃.

1 7. A magnetic read head as claimed in claim 4 wherein the
2 antiferromagnetic metallic layer is selected from the group Ir-Mn, Ni-Mn, Rh-Mn, Pt-
3 Mn, Pd-Pt-Mn and Cr-Pt-Mn.

1 8. A magnetic read head as claimed in claim 4 wherein the non-magnetic
2 seed layer is Ta, the free layer is Ni-Fe, the spacer layer is Cu, the pinned layer is Co and
3 the antiferromagnetic metallic layer is Ni-Mn.

1 9. A magnetic read head as claimed in claim 8 wherein the
2 antiferromagnetic oxide film is selected from the group NiO and α -Fe₂O₃.

1 10. A magnetic read head as claimed in claim 4 wherein the antiferromagnetic
2 oxide film is NiO and the ferromagnetic film of each of the first and second lead layers
3 is Ni-Fe.

1 11. A magnetic read head as claimed in claim 4 wherein the second gap layer
2 interfacially engages the antiferromagnetic metallic film.

1 12. A magnetic read head as claimed in claim 11 wherein the
2 antiferromagnetic metallic layer is Ni-Mn.

1 13. A magnetic read head as claimed in claim 12 wherein a thickness of the
2 antiferromagnetic metallic film is 15 - 25 nm.

1 14. A magnetic read head as claimed in claim 13 wherein the
2 antiferromagnetic oxide film is NiO and the ferromagnetic film of each of the first and
3 second lead layers is Ni-Fe.

1 15. A merged magnetic head that has a read head and a write head wherein
2 each head forms a portion of an air bearing surface (ABS) comprising:

3 said read head including:

4 a read region that has first and second sides that extend substantially
5 perpendicular to the ABS, first and second end regions that are adjacent said first
6 and second sides respectively and the read region and first and second end
7 regions being adjacent said ABS;

8 a read sensor located in the read region and having first and second side
9 edges that define said first and second sides of the read region;

10 said read sensor including:

11 a ferromagnetic free layer and a ferromagnetic pinned layer; and

12 an electrically conductive non-magnetic spacer layer sandwiched

13 between the free and pinned layers;

14 first and second lead layers located in the first and second end regions,
15 each lead layer having a first side edge wherein the first side edge of the first lead
16 layer is adjacent the first side edge of the read sensor and the first side edge of the
17 second lead layer is adjacent the second side edge of the read sensor;

18 first and second gap layers wherein each gap layer is located in the read
19 and first and second end regions;

the read sensor and the first and second gap layers being sandwiched between the first and second shield layers;

the first read gap layer comprising a bi-layer of an insulation film and an antiferromagnetic oxide film sandwiched between the first shield layer and the first lead layer in the first end region, sandwiched between the first shield layer and the read sensor in the read region and sandwiched between the first shield layer and the second lead layer in the second end region;

the free layer being located between the antiferromagnetic oxide film and the pinned layer; and

the first and second lead layers exchange coupling to the antiferromagnetic oxide film and magnetostatically coupling the read sensor; and said write head including:

first and second pole piece layers wherein the first pole piece layer is a common layer with said second shield layer;

a write gap layer;

the first and second pole piece layers being separated by the write gap layer at the ABS and connected together at a back gap;

an insulation stack with at least one coil layer embedded therein; and

the insulation stack being sandwiched between the first and second pole piece layers and being located between the ABS and said back gap.

16. A merged magnetic head as claimed in claim 15 comprising:
the read sensor including:

an antiferromagnetic metallic layer exchange coupling to the pinned layer;
and

a non-magnetic layer sandwiched between the free layer and the antiferromagnetic oxide film in the read region;

7 each of the first and second lead layers having a ferromagnetic film;
8 the ferromagnetic film of each of the first and second lead layers exchange
9 coupling to the antiferromagnetic oxide film in the first and second end regions
10 respectively and magnetostatically coupling to the read sensor;
11 a non-magnetic adhesion film and cap film;
12 an electrically conductive non-magnetic film sandwiched between non-magnetic
13 adhesion and cap films; and
14 in each of the first and second lead layers, the ferromagnetic film being
15 sandwiched between the non-magnetic adhesion film and the antiferromagnetic oxide
16 film in the first and second end regions.

1 17. A merged magnetic head as claimed in claim 16 wherein the
2 antiferromagnetic oxide film is selected from the group NiO and α -Fe₂O₃.

1 18. A merged magnetic head as claimed in claim 17 wherein the
2 antiferromagnetic metallic layer is selected from the group Ir-Mn, Ni-Mn, Rh-Mn, Pt-
3 Mn, Pd-Pt-Mn and Cr-Pt-Mn.

1 19. A merged magnetic head as claimed in claim 16 wherein:
2 the antiferromagnetic metallic layer is Ni-Mn and is interfacially engaged by the
3 second gap layer.

1 20. A merged magnetic head as claimed in claim 19 wherein:
2 a thickness of the antiferromagnetic metallic layer is 15 - 25 nm; and
3 the antiferromagnetic oxide film is NiO and the ferromagnetic film of each of the
4 first and second lead layers is Ni-Fe.

1 21. A magnetic disk drive that includes at least one merged magnetic head
2 that has an air bearing surface (ABS), the disk drive comprising:

3 the merged magnetic head having a write head portion that includes:

4 a read region that has first and second sides that extend substantially
5 perpendicular to the ABS, first and second end regions that are adjacent said first
6 and second sides respectively and the read region and first and second end
7 regions being adjacent said ABS;

8 a read sensor located in the read region and having first and second side
9 edges that define said first and second sides of the read region;

10 said read sensor including:

11 a ferromagnetic free layer and a ferromagnetic pinned layer;

12 an electrically conductive non-magnetic spacer layer sandwiched
13 between the free and pinned layers;

14 first and second lead layers located in the first and second end regions,
15 each lead layer having a first side edge wherein the first side edge of the first lead
16 layer is adjacent the first side edge of the read sensor and the first side edge of the
17 second lead layer is adjacent the second side edge of the read sensor;

18 first and second gap layers wherein each gap layer is located in the read
19 and first and second end regions;

20 the read sensor and the first and second gap layers being sandwiched
21 between the first and second shield layers;

22 the first read gap layer comprising a bi-layer of an insulation film and an
23 antiferromagnetic oxide film sandwiched between the first shield layer and the
24 first lead layer in the first end region, sandwiched between the first shield layer
25 and the read sensor in the read region and sandwiched between the first shield
26 layer and the second lead layer in the second end region;

27 the free layer being located between the antiferromagnetic oxide film and
28 the pinned layer; and

29 the first and second lead layers exchange coupling to the
30 antiferromagnetic oxide film and magnetostatically coupling to the read sensor;
31 and

32 the merged magnetic head having a write head portion that includes:

33 first and second pole piece layers wherein the first pole piece layer is a
34 common layer with said second shield layer;

35 a write gap layer;

36 the first and second pole piece layers being separated by the write gap
37 layer at the ABS and connected together at a back gap;

38 an insulation stack with at least one coil layer embedded therein; and
39 the insulation stack being sandwiched between the first and second pole piece
40 layers and being located between the ABS and said back gap;

41 a frame;

42 a magnetic disk rotatably supported on the frame;

43 a support mounted on the frame for supporting the merged magnetic head
44 in a transducing relationship with the magnetic disk;

45 means for rotating the magnetic disk;

46 positioning means connected to the support for moving the merged
47 magnetic head to multiple positions with respect to said magnetic disk; and

48 means connected to the merged magnetic head, to the means for rotating
49 the magnetic disk and to the positioning means for exchanging signals with the
50 merged magnetic head, for controlling movement of the magnetic disk and for
51 controlling the position of the merged magnetic head.

1 22. The magnetic disk drive as claimed in claim 21, comprising:
2 the read sensor including:
3 an antiferromagnetic metallic layer exchange coupling to the pinned
4 layer; and
5 an electrically conductive non-magnetic layer sandwiched between the
6 free layer and the antiferromagnetic oxide film in the read region;
7 each of the first and second lead layers having a ferromagnetic film; and
8 the ferromagnetic film of each of the first and second lead layers exchange
9 coupling to the antiferromagnetic oxide film in the first and second end regions
10 respectively and magnetostatically coupling to the read sensor;
11 wherein each lead layer includes:
12 a non-magnetic adhesion film and a cap film;
13 an electrically conductive film sandwiched between the non-magnetic
14 adhesion and cap films; and
15 in each of the first and second lead layers, the ferromagnetic film being
16 sandwiched between the non-magnetic adhesion film and the antiferromagnetic
17 oxide film in the first and second end regions.

1 23. A method of making a magnetic read head wherein the read head has a
2 read region that has first and second sides that extend substantially perpendicular to the
3 ABS, first and second end regions that are adjacent the first and second sides respectively
4 and the read region and first and second end regions being adjacent the ABS, comprising:
5 forming a first shield layer;
6 forming an insulation layer on the first shield layer;
7 forming an antiferromagnetic oxide film on the insulation film;

8 forming a spin valve sensor with a non-magnetic layer directly on a first gap
9 layer, the first gap layer comprising a bi-layer of said insulation film and said
10 antiferromagnetic oxide film;

11 forming a mask on the spin valve sensor with first and second openings at first
12 and second lead layer sites wherein the first and second openings define first and second
13 side edges of a spin valve sensor to be located in the read region;

14 milling away spin valve sensor material in the first and second openings to
15 expose the antiferromagnetic oxide film;

16 forming first and second lead layers on the antiferromagnetic oxide film in the
17 first and second openings;

18 removing the mask;

19 forming a second gap layer on the spin valve sensor and the first and second lead
20 layers; and

21 forming a second shield layer on the second gap layer.

1 24. A method as claimed in claim 23 wherein the first and second lead layers
2 have a ferromagnetic film formed directly on the antiferromagnetic oxide film in the first
3 and second end regions respectively.

1 25. A method as claimed in claim 24 wherein the spin valve sensor is formed
2 in the presence of a magnetic field that is directed perpendicular to the ABS and the first
3 and second lead layers are formed in the presence of a magnetic field that is directed
4 parallel to the ABS.

26. A method of making a magnetic read head wherein the read head has a read region that has first and second sides that extend substantially perpendicular to the ABS, first and second end regions that are adjacent the first and second sides respectively and the read region and first and second end regions being adjacent the ABS, comprising:

- forming a first shield layer;
- forming an insulation film on the first shield layer;
- forming an antiferromagnetic oxide film on the insulation film;
- forming a spin valve sensor on a first read gap layer which comprises bi-layer of said insulation film and said antiferromagnetic oxide film;
- said forming of the spin valve sensor including:
 - forming a non-magnetic seed layer directly on the antiferromagnetic oxide film;
 - forming a ferromagnetic free layer on the non-magnetic seed layer;
 - forming a electrically conductive non-magnetic spacer layer on the free layer;
 - forming a ferromagnetic pinned layer on the electrically conductive non-magnetic spacer layer;
 - forming an antiferromagnetic metallic layer of Ni-Mn on the ferromagnetic pinned layer;
 - forming a cap layer on the antiferromagnetic metallic layer;
 - annealing the ferromagnetic pinned layer and the antiferromagnetic metallic layer of Ni-Mn at 240°-280° for 2-10 hours in a field that is directed transverse to the ABS;
- forming a mask with first and second openings at the first and second end regions wherein the first and second openings define said first and second sides of the read region;

27 milling away the spin valve sensor within each of the first and second
28 openings to expose the antiferromagnetic oxide film;
29 forming first and second lead layers on the antiferromagnetic oxide film
30 in the first and second openings respectively; and
31 removing the mark;
32 milling away the cap layer and a portion of the antiferromagnetic metallic
33 layer of the spin valve sensor and a portion of the cap layer of the first and
34 second lead layers;
35 forming a second read gap layer on the antiferromagnetic metallic layer and on
36 the first and second lead layers; and
37 forming a second shield layer on the second read gap layer.

1 27. A method as claimed in claim 26 wherein the antiferromagnetic oxide
2 film is NiO.

1 28. A method as claimed in claim 27 wherein the forming each of the first
2 and second lead layers comprises:
3 forming a soft ferromagnetic film directly on the antiferromagnetic oxide film
4 portion in a respective end region;
5 forming a non-magnetic adhesion film on a respective soft ferromagnetic film in
6 a respective end region;
7 forming an electrically conductive non-magnetic film on a respective non-
8 magnetic adhesion film in a respective end region; and
9 forming a non-magnetic cap layer on a respective electrically conductive non-
10 magnetic film in a respective end region.

1 29. A method as claimed in claim 28 wherein the first and second lead layers
2 are formed in the presence of a field that is directed parallel to the ABS.

1 30. A method of making a magnetic read head that has an air bearing surface
2 (ABS), a read region that has first and second sides that extend substantially
3 perpendicular to the ABS, first and second end regions that are adjacent the first and
4 second sides respectively and the read region and first and second end regions being
5 adjacent the ABS, comprising:
6 forming a read sensor in the read region with first and second side edges that
7 define said first and second sides of the read region as follows:
8 forming a ferromagnetic free layer and a ferromagnetic pinned layer;
9 forming an electrically conductive non-magnetic spacer layer between the
10 free and pinned layers;
11 forming an antiferromagnetic metallic layer that exchange couples to the
12 pinned layer; and
13 forming a cap layer, on the antiferromagnetic metallic layer;
14 forming first and second lead layers in the first and second end regions with each
15 lead layer having a first side edge wherein the first side edge of the first lead layer is
16 adjacent the first side edge of the read sensor and the first side edge of the second lead
17 layer is adjacent the second side edge of the read sensor;
18 forming first and second gap layers with each gap layer located in each of the
19 read and first and second end regions;
20 forming the read sensor and the first and second gap layers between the first and
21 second shield layers;
22 forming an antiferromagnetic oxide film between an insulation film and the first
23 lead layer in the first end region, between the insulation film and the read sensor in the
24 read region and between the insulation film and the second lead layer in the second end

25 region with the first and second lead layers being exchange coupling to the
26 antiferromagnetic oxide film and magnetostatically coupling to the read sensor; and
27 the forming of the read sensor locating the free layer between the
28 antiferromagnetic oxide film and the pinned layer

1 31. A method as claimed in claim 30 including:
2 forming each of the first and second lead layers with a ferromagnetic film so that
3 the ferromagnetic film of each of the first and second lead layers exchange couples to the
4 antiferromagnetic oxide film in the first and second end regions respectively and
5 magnetostatically couples the read sensor.

1 32. A method as claimed in claim 31 wherein the making of each lead layer
2 includes:
3 forming non-magnetic adhesion and cap films;
4 forming an electrically conductive non-magnetic film between the non-magnetic
5 adhesion and cap films; and
6 in each of the first and second lead layers, forming the ferromagnetic film
7 between the non-magnetic adhesion film and the antiferromagnetic oxide film in the first
8 and second end regions, respectively.

1 33. A method as claimed in claim 32 wherein the antiferromagnetic metallic
2 layer is selected from the group Ir-Mn, Ni-Mn, Rh-Mn, Pt-Mn, Pd-Pt-Mn and Cr-Pt-Mn.

1 34. A method as claimed in claim 32 wherein the antiferromagnetic oxide
2 film is selected from the group NiO and α -Fe₂O₃.

1 35. A method as claimed in claim 34 wherein the antiferromagnetic metallic
2 layer is selected from the group Ir-Mn, Ni-Mn, Rh-Mn, Pt-Mn, Pd-Pt-Mn and Cr-Pt-Mn.

1 36. A method as claimed in claim 32 wherein the non-magnetic seed layer
2 is Ta, the free film is Ni-Fe, the spacer layer is Cu, the pinned layer is Co and the
3 antiferromagnetic metallic layer is Ni-Mn.

1 37. A method as claimed in claim 36 wherein the antiferromagnetic oxide
2 film is selected from the group NiO and α -Fe₂O₃.

1 38. A method as claimed in claim 32 wherein the antiferromagnetic oxide
2 film is NiO and the ferromagnetic film of each of the first and second lead layers is Ni-
3 Fe.

1 39. A method as claimed in claim 32 wherein the second gap layer
2 interfacially engages the antiferromagnetic metallic layer.

1 40. A method as claimed in claim 39 wherein the antiferromagnetic metallic
2 layer is Ni-Mn.

1 41. A method as claimed in claim 40 wherein a thickness of the metallic
2 antiferromagnetic layer is 15 - 25 nm.

1 42. A method as claimed in claim 41 wherein the antiferromagnetic oxide
2 film is NiO and the ferromagnetic film of each of the first and second lead layers is Ni-
3 Fe.

Sub 47
43. A method of making a merged magnetic head that has a read head and a write head wherein each head forms a portion of an air bearing surface (ABS) and the read head has a read region that has first and second sides that extend substantially perpendicular to the ABS, first and second end regions that are adjacent the first and second sides respectively and the read region and first and second end regions being adjacent the ABS, comprising:

making the read head as follows:

forming a multi-layered read sensor in the read region with first and second side edges that define said first and second sides of the read region, and with one of its layers being a non-magnetic layer;

forming first and second lead layers in the first and second end regions with each lead layer having a first side edge wherein the first side edge of the first lead layer is adjacent the first side edge of the read sensor and the first side edge of the second lead layer is adjacent the second side edge of the read sensor;

forming first and second insulation gap layers with each insulation gap layer located in each of the read and first and second end regions;

forming the read sensor and the first and second insulation gap layers between the first and second shield layers; and

forming an antiferromagnetic oxide film between the first insulation gap layer film and the first lead layer in the first end region, between the first insulation gap layer and the read sensor in the read region and between the first insulation gap layer and the second lead layer in the second end region with the first and second lead layers exchange coupling to the antiferromagnetic oxide film and magnetostatically coupling to the first and second side edges respectively of the read sensor; and

26 the forming of the read sensor forming the non-magnetic layer directly on
27 the antiferromagnetic oxide film;
28 making the write head as follows:
29 employing the second shield layer as a first pole piece layer;
30 forming a second pole piece layer;
31 forming a write gap layer that separates the first and second pole pieces
32 at the ABS;
33 connecting the first and second pole piece layers at a back gap;
34 forming an insulation stack with at least one coil layer embedded therein
35 between the first and second pole piece layers and between the ABS and said
36 back gap.

1 44. A method as claimed in claim 43 comprising:
2 making a read head as follows:
3 forming a ferromagnetic free layer and a ferromagnetic pinned layer;
4 forming an electrically conductive non-magnetic spacer layer between the
5 free and pinned layers;
6 forming an antiferromagnetic metallic layer that exchange couples to the
7 pinned layer; and
8 forming a cap layer;
9 forming each of the first and second lead layers with a ferromagnetic film so that
10 the ferromagnetic film of each of the first and second lead layers exchange couples to the
11 antiferromagnetic oxide film in the first and second end regions respectively and
12 magnetostatically couples to the first and second side edges respectively of the read
13 sensor;
14 forming non-magnetic adhesion and cap films;

15 forming an electrically conductive non-magnetic film between the non-magnetic
16 adhesion and cap films; and
17 in each of the first and second lead layers, forming the ferromagnetic film
18 between the non-magnetic adhesion film and the antiferromagnetic oxide film.

1 45. A method as claimed in claim 44 wherein the antiferromagnetic oxide
2 film is selected from the group NiO and α -Fe₂O₃.

1 46. A method as claimed in claim 45 wherein the antiferromagnetic metallic
2 layer is selected from the group Ir-Mn, Ni-Mn, Rh-Mn, Pt-Mn, Pd-Pt-Mn and Cr-Pt-Mn.

1 47. A method as claimed in claim 44 wherein:
2 the second gap layer interfacially engages the antiferromagnetic metallic layer;
3 and
4 the antiferromagnetic metallic layer is Ni-Mn.

1 48. A method as claimed in claim 47 wherein:
2 a thickness of the antiferromagnetic metallic layer is 15 - 25 nm; and
3 the antiferromagnetic oxide film is NiO and the ferromagnetic film of each of the
4 first and second lead layers is Ni-Fe.

1 49. A spin valve (SV) sensor having end regions separated from each other
2 by a central region, comprising:
3 an SV element located in the central region, and having a magnetic pinned
4 layer;
5 first and second lead layers located in the first and second end regions;
6 and
7 a continuous antiferromagnetic oxide layer located in the end region and
8 the central region;
9 the element and first and second lead layers being located over the
10 antiferromagnetic oxide layer, and the pinned layer being separated from the
11 antiferromagnetic oxide layer by a non-magnetic spacer layer.

add a5
